US009131485B2

(12) **United States Patent**
Ronneke et al.

(10) **Patent No.: US 9,131,485 B2**
(45) **Date of Patent: Sep. 8, 2015**

(54) **METHOD FOR REVOCABLE DELETION OF PDN CONNECTION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/509,689**

(22) Filed: **Oct. 8, 2014**

(65) **Prior Publication Data**

US 2015/0023234 A1 Jan. 22, 2015

Related U.S. Application Data

(62) Division of application No. 13/805,088, filed as application No. PCT/EP2012/073744 on Nov. 27, 2012.

(60) Provisional application No. 61/667,627, filed on Jul. 3, 2012.

(51) **Int. Cl.**

H04W 76/04	(2009.01)
H04W 76/02	(2009.01)
H04W 4/00	(2009.01)
H04L 29/12	(2006.01)

(52) **U.S. Cl.**

CPC ***H04W 76/041*** (2013.01); ***H04L 61/2007*** (2013.01); ***H04W 4/005*** (2013.01); ***H04W 76/02*** (2013.01); ***H04W 76/04*** (2013.01); *H04L 61/6068* (2013.01); *H04W 76/028* (2013.01)

(58) **Field of Classification Search**

CPC H04W 76/04; H04W 36/14; H04W 80/04; H04W 76/062; H04W 88/16

USPC 370/310, 331, 328, 329, 401

See application file for complete search history.

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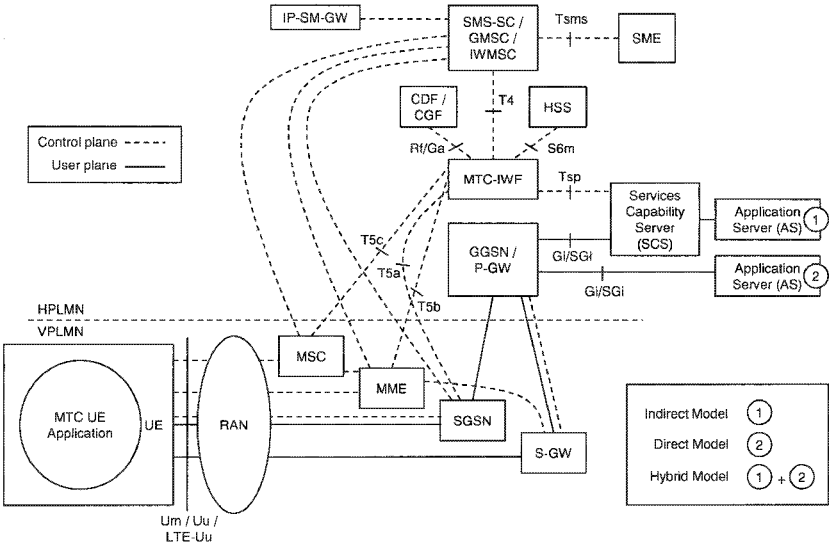
(57) **ABSTRACT**

The invention relates to a method of operating a network node in a telecommunication network, such as an MME. The method comprising: initiating a PDN connection revocable deletion procedure for a device when at least one predetermined criterion is fulfilled; sending a PDN connection revocable deletion request to another network node; receiving a PDN connection revocable deletion response message from said other second network node; and storing data indicating that a PDN connection with said device is revocably deleted.

17 Claims, 4 Drawing Sheets



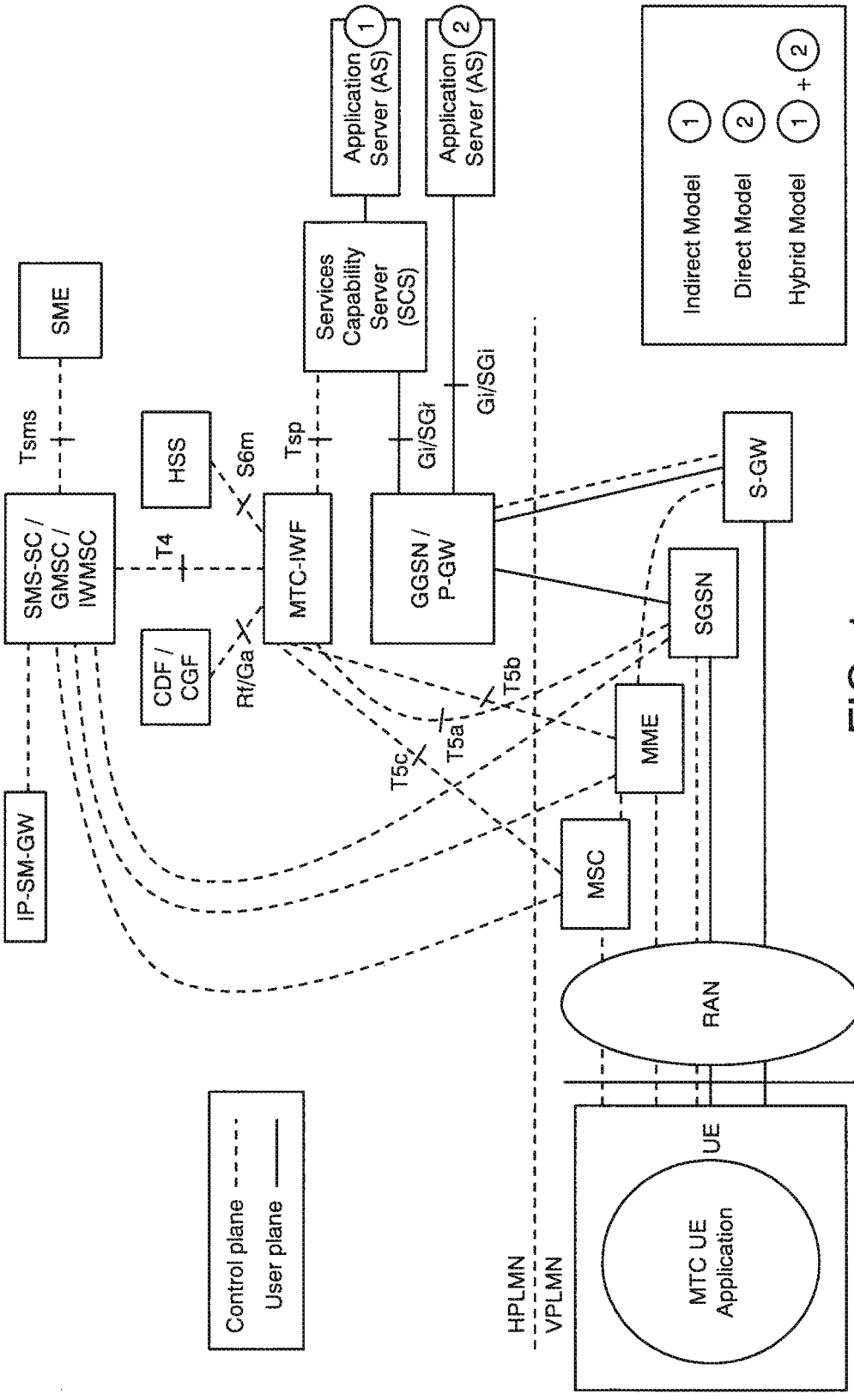

Application Server (AS) 1
Application Server (AS) 2
Indirect Model 1
Direct Model 2
Hybrid Model 1 + 2
SME
Services Capability Server (SCS)
Tsms
HSS
S6m
Tsp
Gi/SGi
Gi/SGi
SMS-SC / GMSC / IWMSC
T4
MTC-IWF
GGSN / P-GW
S-GW
SGSN
CDF / CGF
Rf/Ga
T5b
T5a
T5c
MME
IP-SM-GW
MSC
RAN
Um / Uu / LTE-Uu
UE
MTC UE Application
HPLMN
VPLMN
Control plane
User plane

FIG. 1

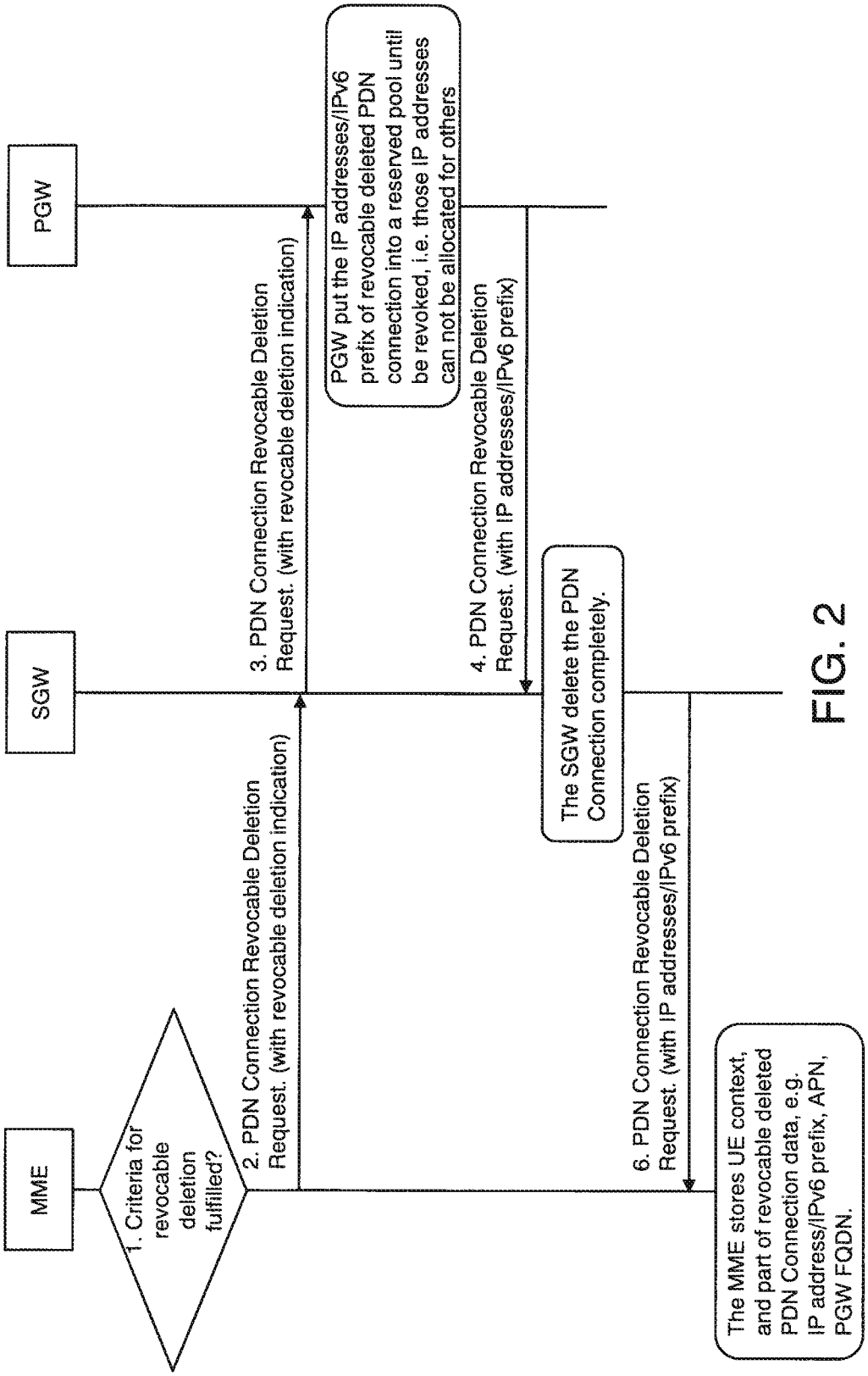

MME
SGW
PGW
1. Criteria for revocable deletion fulfilled?
2. PDN Connection Revocable Deletion Request. (with revocable deletion indication)
3. PDN Connection Revocable Deletion Request. (with revocable deletion indication)
PGW put the IP addresses/IPv6 prefix of revocable deleted PDN connection into a reserved pool until be revoked, i.e. those IP addresses can not be allocated for others
4. PDN Connection Revocable Deletion Request. (with IP addresses/IPv6 prefix)
The SGW delete the PDN Connection completely.
6. PDN Connection Revocable Deletion Request. (with IP addresses/IPv6 prefix)
The MME stores UE context, and part of revocable deleted PDN Connection data, e.g. IP address/IPv6 prefix, APN, PGW FQDN.

FIG. 2

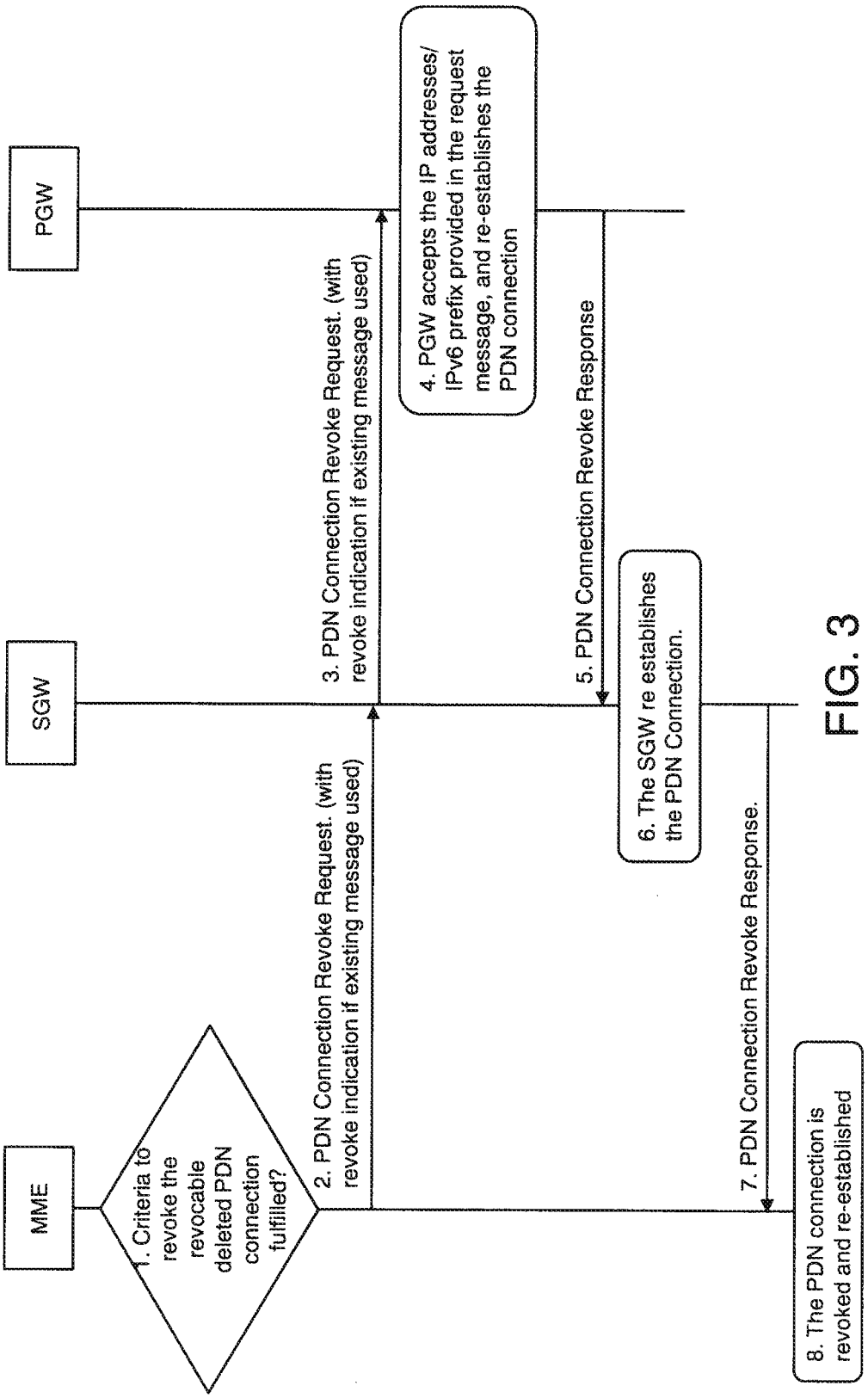

MME
SGW
PGW
1. Criteria to revoke the revocable deleted PDN connection fulfilled?
2. PDN Connection Revoke Request. (with revoke indication if existing message used)
3. PDN Connection Revoke Request. (with revoke indication if existing message used)
4. PGW accepts the IP addresses/ IPv6 prefix provided in the request message, and re-establishes the PDN connection
5. PDN Connection Revoke Response
6. The SGW re establishes the PDN Connection.
7. PDN Connection Revoke Response.
8. The PDN connection is revoked and re-established

FIG. 3

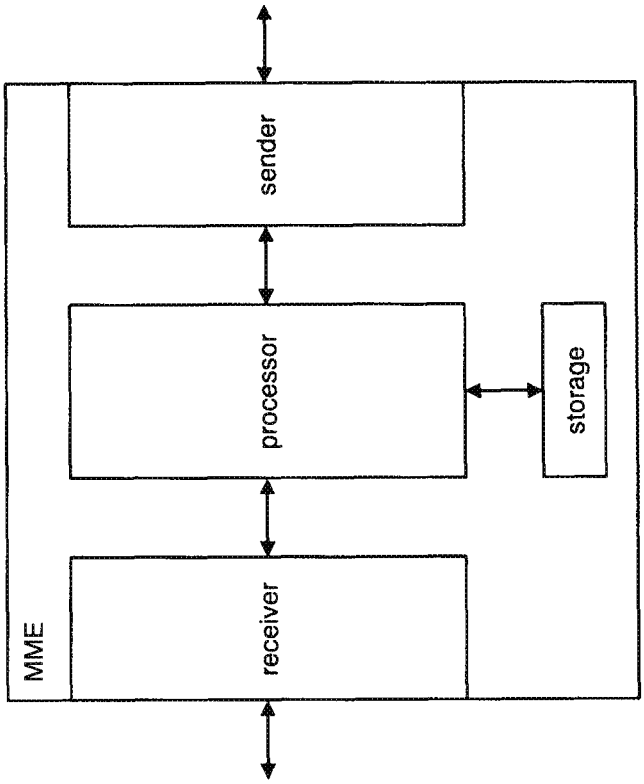


FIG. 4

METHOD FOR REVOCABLE DELETION OF PDN CONNECTION

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a divisional of U.S. application Ser. No. 13/805,088 filed on Dec. 18, 2012 (published as 2014/0050132), which i) is a 35 U.S.C. §371 National Phase Application from international application PCT/EP2012/073744, filed Nov. 27, 2012, and designating the United States, which international application claims priority to U.S. Provisional Application No. 61/667,627, filed Jul. 3, 2012 and ii) claims the benefit of U.S. Provisional Application No. 61/667,627, filed Jul. 3, 2012. The above-identified applications and publications are incorporated by reference herein.

TECHNICAL FIELD

The present invention relates to a method of operating a network node in a telecommunication network, such as an MME. The present invention also relates to a network node for a telecommunication network, such as an MME. The invention generally relates to the field of 3GPP telecommunication networks. In particular, it relates to PDN connections in such networks.

BACKGROUND

3GPP is currently investigating enhancement of machine type device communication (MTC) for release 12.

One category of machine type devices are defined as only requiring "infrequent communication", that is, they only communicate very seldom, e.g. one or a few IP packets a week or a month. The number of this type of devices can be huge, several times more than the normal type of terminals in the network. Therefore using normal network procedures for these devices may require disproportional large amount of network resources and hence optimizations are needed. Optimizations are also needed to avoid the risk of network overloading from these large numbers of devices.

The requirement from operators is to reduce the resource usage for devices that only communicate very rarely and stay silent for long times. In particular it can be noted that maintaining the default PDN connection in EPS networks is seen as a costly resource usage. But the optimization is of course also needed for devices with more than one (the default) PDN connection.

Some operators have suggested to establish the PDN connection and allocate resources in the PGW and SGW only at the rare occasions when communication from or to these type of devices is actually done. In this way, no memory resources or other resources are allocated in the PGW and SGW at all, and no mobility (MM) related signalling is required between the MME and SGW/PGW when the devices are moving. By keeping the devices attached (registered) in the network, the devices can be reached in case of mobile terminated (MT) communication e.g. from an SCS/MTC Server.

There are some requirements specified in stage 1 document, TS 22.368: "The system shall provide mechanisms to efficiently maintain connectivity for a large number of MTC Devices." and "MTC Devices may keep their data connection or not keep their data connection when not communicating, depending on operator policies and MTC Application requirements."

Another feature that is also being discussed in 3GPP SA2 is a new UE state mode, a so-called sleep mode. When a UE is in sleep mode, the UE may not be immediately reachable by the network. It would only be reachable when the device wakes up and does some signalling to the network, e.g. in conjunction to the periodic tracking area update (TAU) signalling (i.e. the periodic "keep alive" signalling in 3GPP networks). Devices using the UE sleep mode state will probably not communicate very often and are likely to be good candidates for belonging to the "infrequently communicating" devices, and hence benefit from the optimization proposed in this invD.

The problem with infrequently communicating devices in LTE networks is that the LTE standard is defined to use the "always connected" paradigm. That is, an attached LTE device does always have a PDN connection. And that will consume resources and create signaling in the network as described above.

SUMMARY OF THE INVENTION

Consequently, it is an object of the present invention to solve the above-mentioned problem and provide a method for reducing the resource usage for devices that only communicate very rarely and stay silent for long times. In particular it can be noted that the invention provides a core network optimization solution to minimize the signalling and consumed network resources for "infrequently communicating" devices.

In order to obtain this object, the present invention relates to a method of operating a network node in a telecommunication network, such as an MME, the method comprising: initiating a PDN connection revocable deletion procedure for a device when at least one predetermined criterion is fulfilled; sending a PDN connection revocable deletion request to another network node; receiving a PDN connection revocable deletion response message from said other second network node; and storing data indicating that a PDN connection with said device is revocably deleted.

In order to obtain said object, the invention also relates to a network node for a telecommunication network, such as an MME, said node being configured for: initiating a PDN connection revocable deletion procedure for a device when at least one predetermined criterion is fulfilled; sending a PDN connection revocable deletion request to another network node; receiving a PDN connection revocable deletion response message from said other second network node; and storing data indicating that a PDN connection with said device is revocably deleted.

In order to minimize the impact on the standard and avoid UE (device) impact, it is proposed to introduce new network procedures, referred to as a "PDN connection deletion with IP addresses reservation" procedure and a "PDN connection re-establishment using reserved IP addresses" procedure in the Evolved Packet System (EPS). That is, the EPS attach procedure is not changed and the default PDN connection is still established when the device is initially attaching, but after the attach has been done, the default PDN connection (and any other PDN connections of the device) are deleted (but can be revoked later) and resources released in the network, i.e. PDN Connection(s) are deleted in the PGW and SGW while the UE context and part of PDN connection (which is used to recover the deleted PDN connection) is kept in the MME.

The method according to the invention provides certain advantages, i.e. one or more of the following: resources in the network for infrequently communicating devices/terminals will be saved; there are no PGW and no SGW resources required for suspended (i.e. being in revocable deletion state)

devices; it avoids unnecessary signalling, e.g. inter MME mobility and/or inter SGW mobility where the PGW does not need to be informed; it improves the possibilities for operators to make sound business agreements with M2M service providers for use cases where devices communicate very little and seldom; it improves and lowers the cost of machine type communication; it has limited impacts on the existing system, and no impact on the UE (device) and no impact on the NAS protocols; it saves network storage space; and it proposes a mechanism to provide a different treatment to those UE's that are configured for the machine type device communication without impact on legacy implementation.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be described below with reference to certain embodiments and the enclosed drawings, in which:

FIG. **1** is a schematical figure of a network in which the invention can be implemented;

FIG. **2** is a communication scheme of the so-called "PDN connection deletion with reserved IP addresses procedure" according to an embodiment of the invention;

FIG. **3** shows a communication scheme of the so-called "PDN connection re-establishment with reserved IP addresses procedure" according to an embodiment of the invention; and

FIG. **4** schematically shows an example of a network node, in this case an MME.

DETAILED DESCRIPTION

According to an embodiment, a new functionality in the mobility management node, e.g. MME node, is provided. The functionality may be built into other similar types of network nodes, such as a SGSN which is used for GERAN/UTRAN, or an ePDG or a TWAN for non-3GPP-access, e.g. WLAN. Below, mostly the term MME is used, but it is noted that this is only used as an example.

FIG. **1** schematically shows an example of a network in which certain embodiments of the invention can be implemented. In FIG. **1**, the dotted lines indicate communication between modules in the control plane. The continuous lines represent communication in the user plane.

A method of revocable deletion of PDN connections will now be described. Firstly, it should be noted that the new core network procedures are to delete the established PDN connection(s) on the network side without the UE knowing and to revoke them with the same IP address when they are needed again. The deletion can be triggered by the network (MME/SGSN/ePDG/non-3GPP-access) based on different criteria. Examples of such criteria are: a certain time period after the attach procedure is finished; when a device has been inactive for a certain time period; when a device is moved to idle mode; when a device goes into sleep mode; a device which has a certain subscription parameter, set e.g. "infrequently communicating" device; a device where collected traffic statistics of this device in the network show that resources would be saved if the suspend procedures are used; a combination of two or more criteria above.

The revocable deletion function should be applied on UEs (i.e. devices) based on a parameter in the subscription information in HSS. It can also be enabled based on some indication from the UE/device e.g. the Low Access Priority Indication or other new or existing indication. It can also be enabled based on information configured into the MME (e.g. IMSI ranges) or configured into any other node.

Revocable deletion of PDN connection procedures should preferably only be done when the device is in idle mode. It is also transparent to the device, meaning that the device functionality does not need to be impacted in any way. According to an embodiment, when the PDN connection is deleted, the allocated resources for the PDN connection are released in the PGW and SGW. However, the PGW is required to place the allocated IP Addresses/prefix for the deleted PDN connection to a so-called reserved IP address pool, and the IP address/IPv6 Prefix shall not be allocated to any other PDN connection. Some resources related to the PDN connection may also be released in the MME, but sufficient information will be kept in the MME to enable the PDN connection to be re-established again by the revoke procedure.

When the PDN connection(s) are deleted for a device/UE, the device may not receive any DL traffic nor send any UL traffic. Neither may it receive any paging related to the PDN connection(s) e.g. paging due to downlink data notification (DDN) from DL IP packets arriving to the SGW. When traffic needs to be sent, the PDN connection will first be revoked.

Regarding IP address handling, it can be noted that when a PDN connection is deleted by the MME, the IP address(es) and/or IPv6 Prefix(es) of the PDN connection of the device may be either released or kept reserved by the network. If it is released a new IP address/IPv6 prefix will be assigned to the PDN connection when it is revoked. The device must then be informed of the new IP address/IPv6 prefix when it is revoked.

If the IP address(es)/IPv6 prefix(es) are "kept reserved during deletion", it/they must be stored until the PDN connection is revoked/re-established. This procedure may include a step of passing the IP address(es) or IPv6 Prefixes from the PGW to the MME at deletion, and back from the MME to the PGW at revoke (re-establishment).

A PDN connection normally only has one IP address but nothing prevents it from having several. For example, when it operates as a UE Gateway it may have more than one IP address. A PDN connection may also have both an IPv4 address and an IPv6 address (dual stack). For IPv6, the network (i.e. PGW) assigns only the first 64 bits of the IPv6 address i.e. the "IPv6 Prefix". The UE is assigns the last 64 bits itself, i.e. the "Interface Identifier", IID.

A process of notifying an SCS will now be described. In case the device is communicating with an SCS, the SCS may optionally be informed by the MME when the PDN connection(s) of a device are deleted and revoked. In this manner, the SCS knows it cannot initiate IP communication with the device, but needs to send a device trigger to the device for the device first to establish the PDN connection(s).

This notification could be sent from the MME (or SGSN) via the T5b (or T5a) interface to the MTC-IWF. If the MME knows the SCS identity of the device, it can include the SCS identity in the message to the MTC-IWF. The MTC-IWF resolves the address of the SCS by DNS and/or HSS query and forwards the deletion or revoke notification to the SCS.

The notification can also be sent from the PGW when a PDN connection is deleted or revoked. The RADIUS/Diameter protocol on the Gi/SGi interface may then be used. This interface may be enhanced in order to tell the SCS that the deletion of the PDN connection is revocable, so that the SCS knows that the deletion is not known by the device, only made internally in the network, and that the same IP address will be used when the connection later is up again.

Revoking a previously deleted PDN connection is done by the network (MME/SGSN/ePDG/non-3GPP-access) based on different triggering criteria. Examples of such criteria are: a Service Request for establishing the bearers is received

from a device with a revocable deleted PDN connection; a Device Trigger is received in the MME for a device with a revocable deleted PDN connection.

The PDN connection revoke procedure is transparent to the device. When the PDN connection is revoked, the PDN connection is re-established. If the IP address has been kept reserved during the revocable deletion, the PDN connection shall be re-established using the same IP address/IPv6 prefix as was used before the revocable deletion.

The IP address/IPv6 Prefix shall then be included in the revoke message from MME to SGW/PGW.

When the network decides to revocable delete the PDN Connection of a device, i.e. when any of the criteria described above related to revocable deletion of PDN connections are fulfilled, the MME (or SGSN/ePDG/non-3GPP access) shall initiate the PDN connection deletion with reserved IP addresses procedure. When one of the criteria as mentioned above are fulfilled, the network decides to revoke the PDN Connection, and the MME (or SGSN/ePDG/non-3GPP access) shall initiate the PDN connection re-establishment with reserved IP addresses procedure. Instead of a MME, other network nodes could perform the methods described, such as a SGSN, ePDG, or TWAN for non-3GPP access. In case of ePDG/TWAN, there is no SGW in the network of FIG. **1**.

A so-called PDN connection deletion with reserved IP addresses procedure may use existing procedures with some modifications, e.g. UE or MME requested PDN disconnection which is using Delete Session Request/Response message, or MME initiated Suspend procedure when UE performs CSFB or SRVCC to a non-DTM supported RAN which is using Suspend Notification/Acknowledge message. This procedure is currently specified in 3GPP to be only used for suspend User plane. However, according to a embodiment, the procedure evolves to delete the PDN Connection in SGW and PGW. Alternatively, this procedure can be defined as a complete new procedure using new signalling messages.

According to an embodiment, information is exchanged between the MME and the PGW comprising a new indication which indicates to the PGW that the IP address(es)/IPv6 Prefix that have been allocated for the revocable deleted PDN connection, shall remain reserved in the PGW and not be moved to the pool of free IP address/IPv6 Prefixes of the PGW, and that the PGW shall include the UE's IP address/IPv6 Prefixes in the revocable deletion response message. The reserved IP address(es)/IPv6 Prefix(es) shall preferably be stored in the MME.

If existing messages are to be re-used, a new indication, referred to as a "revocable deletion indication" can be included in the revocable deletion request message e.g. Delete Session Request message or Suspend Notification, and in the revocable deletion response message, e.g. the Delete Session Response or Suspend Acknowledge message, a new parameter carrying the IP addresses/IPv6 Prefix of the PDN Connection may be returned to the MME (for storage until the PDN connection is revoked).

Both messages between the MME<->SGW and between SGW<->PGW are modified in the same way.

Alternatively, a pair of new GTPv2-C/PMIPv6 messages can be used for this PDN connection deletion with reserved IP procedure.

The MME/SGSN initiated PDN connection deletion with reserved IP addresses procedure is triggered when a criteria is fulfilled as specified in the section above describing revoking a previously deleted PDN connection. In the following description with reference to FIG. **2**, a PDN connection revocable deletion request/response is a general term, which may represent a new pair of GTP messages or reuse existing GTP messages e.g. Delete Session Request/Response or Suspend Notification/Acknowledge.

FIG. **2** shows a communication scheme of the so-called PDN connection deletion with reserved IP addresses procedure according to an embodiment. The following steps are executed by the different nodes indicated in FIG. **2**:

(1) The MME/SGSN initiates the PDN connection revocable deletion procedure when one or more of the criteria above is fulfilled.

(2) The MME/SGSN sends a PDN connection revocable deletion request to the SGW via S4/S11 interface. The SGW forwards the received PDN connection revocable deletion request to the PGW via S5/S8 GTP or S5/S8 PMIP.

(3) The PGW deletes the PDN Connection data. If the IP address/IPv6 Prefix of the PDN connection shall be kept reserved, then the IP address/IPv6 Prefix of the PDN connection shall not be placed in the pool of free IP addresses/IPv6 Prefixes. When the PDN Connection data has been deleted, the PGW is going to discard any received UE downlink data (as for any non-existent PDN connections). The TEID or GRE tunnel with the SGW is released.

(4) The PGW responses to the SGW with PDN connection revocable deletion response message including the IP address/IPv6 Prefix of the deleted PDN connection.

(5) When receiving the response from PGW, the SGW completely releases the UE context and the TEID or GRE tunnel with the PGW.

(6) The SGW forwards PDN connection revocable deletion response message to the MME/SGSN. The MME keeps the UE context and marks PDN contexts as revocable deleted and just keeps some of the stored data for a revocable deleted PDN Connection e.g. the IP address/IPv6 Prefix of the suspended PDN connection, PGW FQDN, APN information. The PGW FQDN is used to find exactly the same PGW again when the PDN connection is revoked.

The so-called PDN connection re-establishment with reserved IP addresses procedure may be a complete new procedure or reuse the existing procedure, e.g. E-UTRAN Initial UE attach procedure or Resume Notification procedure defined in TS 23.216 and TS 23.272.

According to an embodiment, information is exchanged here between the MME and the PGW via the SGW. The stored IP address(es)/IPv6 Prefix, if available, are included by the MME into the message to the PGW, as if static IP address/prefix was used in the revoke request message.

If the existing signalling messages are to be re-used, a new indication is also needed to inform the PGW it is a revoke procedure. The PGW will accept IP address included by the MME and remove it from the reserved IP address/IPv6 Prefix pool (if it kept such a pool).

Both the message between the MME<->SGW and between the SGW<->PGW are modified in the same way. The SGW is just forwarding the new parameters.

Alternatively new pair of GTPv2-C/PMIPv6 messages can be used for the procedure.

The PDN connection re-establishment with reserved IP addresses procedure is triggered when one or more criteria for revoking a PDN connection as specified above in chapter 6.1 is fulfilled. In the following description with reference to FIG. **3**, the PDN connection revoke request/response is used as a general term, which may also represent a new pair of GTP messages or reuse existing GTP messages or the reuse of existing GTP messagest e.g. Create Session Request/Response or Resume Notification/Acknowledge.

FIG. **3** shows a communication scheme of the so-called "PDN connection re-establishment with reserved IP

addresses procedure" according to an embodiment. The following steps are executed by the different nodes indicated in FIG. **3**:

(1) The MME/SGSN initiates the PDN connection re-establishment with reserved IP addresses procedure when one or more criteria above are fulfilled.

(2) The MME/SGSN sends a PDN connection revoke request message with the stored UE's IP address to the SGW via S4/S11 interface. If the existing messages are used, the SGW & PGW will interpret the included IP address/IPv6 Prefix as a static IP address and uses that instead of allocating a new in the pool of free IP addresses/IPv6 prefixes. Another new indication flag may be included to explicitly tell the PGW it is PDN connection re-establishment with reserved IP addresses procedure.

(3) The SGW forwards the received PDN connection revoke Request message to the PGW via S5/S8 GTP or S5/S8 PMIP.

(4) The PGW revokes the deleted PDN Connection, e.g. re-establishing the TEID or GRE tunnel with the SGW, so DL/UL data forwarding is resumed. If an IP address/IPv6 Prefix is included in the received message, the PGW uses that address/prefix instead of allocating a new IP address. The PGW may alternative find the reserved IP address/Prefix stored somewhere else, e.g. in the PGW itself. The IMSI in the request message is then used to find the stored IP address.

(5) The PGW responds to the SGW with PDN connection revoke response message.

(6) When receiving the response from PGW, the SGW setup the PDN Connection, e.g. allocating TEID or GRE, so DL/UL data forwarding is also resumed.

(7) The SGW forward PDN connection revoke response message to the MME/SGSN.

(8) The PDN connection(s) are revoked by the network.

Regarding idle mode mobility, it can be noted that at any idle mode inter MME/SGSN mobility, the information related to the revocable deletion, e.g. Revocable deletion Indication, stored IP addresses/IPv6 Prefix may be included during context transfer procedure. The so-called target MME/SGSN shall take over the responsibility for resuming the PDN connections when needed. If the target MME/SGSN does not support revocable deletion/revoke procedure, the revocable deleted PDN connections may be revoked by the source MME/SGSN as part of the mobility procedure before the target MME/SGSN takes over the responsibility.

Furthermore, regarding a notification of a revocable deletion of PDN Connection it can be noted that a notification may optionally be sent by the MME or the PGW to the SCS as detailed described in the following claues when the PDN connection(s) for a device is revocably deleted and when it is revoked. The SCS can then avoid trying to send IP packets to the device while revocable deleted, which will save some resources in the SCS and the network and shorten the time for when the SCS understands it need to fallback to device triggering.

If the SCS is not aware of the revocably deleted PDN connection of a device and starts to send IP packets to the device, the PGW will just discard the IP packets. The SCS will then after some time understand that the device is not reachable at the moment.

For the optional notification there are a few alternatives on how to notify an SCS of a revocable deletion or revoke event. Among these alternatives are notifications over the T5 interface, over the S6a interface and over the PGW.

Referring firstly to the T5 interface, it is noted that the revocable deletion notification and revoke notifications can be sent to the SCS over T5b/a and Tsp interface.

The revocable delete notification procedure is triggered when the PDN connection(s) of a device are revocable deleted. The following steps may be performed:

1. The MME/SGSN initiates the revocable deletion notification procedure when the PDN connection(s) of a device are revocable deleted.
2. The MME/SGSN sends a revocable deletion notification request to the MTC-IWF via T5 interface. If the MME knows the SCS, it may include the SCS ID or address in the notification message. If the MME knows the External ID it may include the External ID in the notification message
3. The MTC-IWF retrieves the UE's External Identifier and the SCS ID/address from HSS via S6m interface (if not received in step 2).
4. Once having the UE's External Identifier and its SCS address, the MTC-IWF sends a revocable deletion notification request with the UE's external identifier to the SCS via Tsp interface.
5. The SCS marks the device/UE as revocable deleted. No IP communication should be initiated to the device without doing a prior device triggering procedure.
6. A revocable deletion confirmation message may be sent back to MTC-IWF via Tsp interface, which may forward it to MME/SGSN over T5b/a interface.

Furthermore, the revoke notification procedure is triggered when the PDN connection(s) of a device are revoked. This may include the following steps:

1. The MME/SGSN initiates the revoke notification procedure when the PDN connection(s) of a device are revoked.
2. The MME/SGSN sends a revoke notification request to the MTC-IWF via T5 interface. If the MME knows the SCS, it may include the SCS ID or address in the notification message. If the MME knows the External ID it may include the External ID in the notification message
3. The MTC-IWF retrieves the UE's External Identifier and the SCS ID/address from HSS via S6m interface (if not received in step 2).
4. Once having the UE's External Identifier and its SCS address, the MTC-IWF sends a revoke notification request with the UE's external identifier to the SCS via Tsp interface.
5. The SCS unmarks the suspension of the device/UE. The device should now be reachable for IP communication.
6. A revoke confirmation message may be sent back to MTC-IWF via Tsp interface, which may forward it to MME/SGSN over T5b/a interface.

The revocable deletion notification procedure is triggered when the PDN connection(s) of a device are revocable deleted. This may include the following steps:

1. The MME/SGSN initiates the revocable deletion notification procedure when the PDN connection(s) of a device are revocable deleted.
2. The MME/SGSN sends a revocable deletion notification request to the HSS via S6a interface. The HSS may inform the MTC-IWF over S6m interface.
3. The HSS/MTC-IWF shall mark the UE as revocable deleted.
4. Or, the MTC-IWF sends a revocable deletion notification request with the UE's external identifier to the SCS via Tsp interface.
5. The SCS shall mark the device/UE as revocable deleted. No IP communication should be initiated to the device without doing a prior device triggering.

Regarding revoke notification, it is noted that the revoke notification procedure is triggered when the PDN connection(s) of a device are revoked. This may include the following steps:

1. The MME/SGSN initiates the revoke notification procedure when the PDN connection(s) of a device are revoked.
2. The MME/SGSN sends a revoke notification request to the HSS via S6a interface. The HSS may inform the MTC-IWF over S6m interface.
3. The HSS/MTC-IWF shall reset any revocable deletion mark for the UE.
4. Or, the MTC-IWF sends a revoke notification request with the UE's external identifier to the SCS via Tsp interface.
5. The SCS shall unmark the suspension of the device/UE. The device should now be reachable for IP communication.

Furthermore, the revocable deletion/revoke notification can be sent to the SCS over PGW and MTC-AAA interface (SGi/Diameter).

The revocable deletion notification procedure is triggered when the PDN connection(s) of a device are revocable deleted. This may include the following steps:
1. The MME/SGSN initiates the revocable deletion procedure.
2. Once the PDN connection is revocable deleted in the PGW, the PGW sends a revocable deletion notification to the MTC-AAA. This may be part of the normal RADIUS/Diameter messaging on SGi/Gi, e.g. using a new indication in the existing message.
3. The MTC-AAA retrieves the UE's External Identifier from HSS.
4. Once the UE's External Identifier is received from the HSS, the MTC-AAA forwards the revocable deletion notification with the UE's external identifier to the SCS. This may be a new indication as part of the normal RADIUS/Diameter messaging on SGi/Gi.
5. The SCS marks the device/UE as revocable deleted. No IP communication should be initiated to the device without doing a prior device triggering.

The revoke notification procedure is triggered when the PDN connection(s) of a device are revoked. This may include the following steps:
1. The MME/SGSN initiates the revoke procedure.
2. Once the PDN connection is re-established in the PGW, the PGW sends a revoke notification to the MTC-AAA. This may be a new indication as part of the normal RADIUS/Diameter messaging on SGi/Gi.
3. The MTC-AAA retrieves the UE's External Identifier from HSS.
4. Once the UE's External Identifier is received from the HSS, the MTC-AAA forwards the revoke notification with the UE's external identifier to the SCS. This may be a new indication as part of the normal RADIUS/Diameter messaging on SGi/Gi.
5. The SCS unmarks the revoked deletion of the device/UE. The device should now be reachable for IP communication.

The following protocols may be impacted due to the revocable deletion/revoke procedure suggested above: S4/S11 GTPv2-C: new messages or new indicators for MME/SGSN to inform the SGW of revocable deletion/revoke PDN connections; S10 GTPv2-C: new parameters in transferred contexts at idle mode mobility procedures; S5/S8 GTPv2-C: new messages or new indicators for SGW to inform the PGW of revocable deletion/revoke PDN connections; S5/S8 PMIP: new PMIP messages or new indicators in BRI message for SGW to inform the PGW of revocable deletion/revoke PDN connections; T5b/T5a: new messages or new indicators for MME/SGSN to inform the MTC-IWF for revocable deletion/revoke notifications and confirmations; Tsp: new messages or new indicators for MTC-IWF to inform the SCS of revocable deletion/revoke of device connections.

FIG. **4** schematically shows an example of a network node, in this case an MME. The MME comprises a processor for executing commands. Furthermore, the MME comprises a receiver and a sender unit to communicate with other nodes in a telecommunication network. In this example, the MME also comprises a storage for storing information. The processor may be configured to execute the method step described above and store information, e.g. the IP address(es)/IPv6 prefix(es), in the local storage shown in FIG. **4**. The PGW and SGW described above may be represented by the structure of FIG. **4** as well.

It can be noted that the above described embodiments are not restricted to the use in LTE networks. The embodiments may as well be used in GERAN/UTRAN and in other non-3GPP access, e.g. WLAN. The embodiments described above are merely intended to explain the invention, and are not restrictive to the scope of the invention.

ABBREVIATIONS

3GPP 3rd Generation Partnership Project
AS Application Server
CDF Charging Data Function
CGF Charging Gateway Function
DL Downlink
EPC Evolved Packet Core
ePDG evolved Packet Data Gateway
EPS Evolved Packet System
FQDN Fully Qualified Domain Name
GGSN GPRS Gateway Serving Node
SGI It is the reference point between the PDN GW and the packet data network. Packet data network may be an operator external public or private packet data network or an intra operator packet data network, e.g. for provision of IMS services. This reference point corresponds to Gi for 3GPP accesses.
GRE Generic Routing Encapsulation
HPLMN Home Public Land Mobile Network
HSS Home Subscriber Services
IP Internet Protocol
IP-SM-GWIP-Short Message-Gateway
IWF Interworking Function
IWMSC InterWorking MSC
LTE Long Term Evolution
M2M Machine to Machine
MME Mobility Management Entity
MTC Machine Type Communication
PDN Public Data Network
PGW Packet Data Network Gateway
RAN Radio Access Network
SAE System Architecture Evolution
SCS Service Capability Server
SGW Servicing Network Gateway
SGSN Serving GPRS Support Node
SME Short Message Entity
SMC-SC Short Message Service—Service Centre
TAU Track Area Update
TEID Tunnelling Endpoint Identifier
UE User Equipment
UL Uplink
VPLMN Visited Public Land Mobile Network

The invention claimed is:

1. A method in a telecommunication network, the method comprising:
storing a pool of free addresses, wherein each address included in the pool of free addresses is available to be allocated to a user equipment (UE);

receiving, at a first network node, a packet data network (PDN) connection revocable deletion request transmitted by a second network node and identifying a PDN connection being used by a first UE, said PDN connection being associated with PDN connection data and with IP address information allocated to the first UE, the allocated IP address information comprising one or more of an IP address and an IPv6 prefix and the IP address information is not included in the pool of free addresses;

in response to receiving the PDN connection revocable deletion request, the first network node deleting the PDN connection data and reserving said allocated IP address information for said first UE wherein said step of reserving said allocated IP address information for said first UE comprises keeping said allocated IP address information out of the pool of free addresses so that the allocated IP address information is not available to be allocated to any UE other than said first UE since the allocated IP address information is reserved for said first UE; and

responding to the PDN connection revocable deletion request with a PDN connection revocable deletion response message including the allocated IP addresses information.

2. The method of claim **1**, further comprising, prior to the first network node receiving the PDN connection revocable deletion request, the second network node determining whether a certain condition exists, and, as a consequence of the second network node determining that said certain condition exists, the second network node transmitting towards the first network node said PDN connection revocable deletion request.

3. The method of claim **2**, further comprising:

the second network node receiving a certain message pertaining to the UE after sending the PDN connection revocable deletion request;

the second network node transmitting a revoke request as a consequence of receiving the certain message, the revoke request comprising the allocated IP address information;

the first network node receiving the revoke request from a third network node; and

as a consequence of receiving the revoke request from the third network node, the first network node establishing with the third network node a tunnel for use in transmitting to the third network node data destined for the UE.

4. The method of claim **3**, wherein determining whether said certain condition exists comprises determining at least one of:

i) whether at least a certain amount of time has elapsed since the UE completed an attach procedure;

ii) whether the UE has been inactive for at least a certain amount of time; and

iii) whether the UE is in an idle or sleep mode.

5. The method of claim **3**, wherein the certain message pertaining to the UE is a service request message transmitted by the UE.

6. The method of claim **3**, further comprising

one of the first network node and the second network node transmitting towards a server a revocable deletion notification for notifying the server that a PDN connection associated with the device has been revocably deleted.

7. The method of claim **1**, further comprising:

receiving at the first network node a PDN connection revoke request message from said second network node; and

in response to the revoke request message:

revoking the deleted PDN connection in response to the revoke request message; and

transmitting to the second network node a PDN connection revoke response message.

8. The method of claim **1**, further comprising:

the second network node receiving the PDN connection revocable deletion response message; and

in response to the deletion response message, the second network node releasing a UE context associated with the UE.

9. The method of claim **8**, further comprising:

the second network node forwarding the PDN connection revocable deletion response message to a third network node;

the third network node, in response to receiving the PDN connection deletion response message, marks a PDN context for the UE as revocably deleted.

10. A method of operating a network node in a telecommunication network, the method comprising:

receiving a packet data network (PDN) connection revocable deletion request from another network node;

deleting the PDN connection data and put an allocated IP address or an IPv6 prefix for the deleted PDN connection to a reserved address pool;

responding to the other network node with a PDN connection revocable deletion response message including the IF addresses or the IPv6 prefix of the deleted PDN connection;

receiving a PDN connection revoke Request message from said other network node;

revoking the deleted PDN connection; and

responding to the other network node with a PDN connection revoke response message.

11. A first network node for a telecommunication network, said first network node comprising;

a receiver for receiving from a second network node a packet data network (PDN) connection revocable deletion request identifying a PDN connection being used by a first UE, said PDN connection being associated with PDN connection data and with IP address information allocated to the first UE, the allocated IP address information comprising one or more of an IP address and an IPv6 prefix and the IP address information is not included in a pool of free addresses;

a transmitter; and

a processor configured such that, in response to the PDN connection revocable deletion request, the processor:

employs the transmitter to transmit to the second network node a PDN connection revocable deletion response message, and

deletes the PDN connection data and reserves said allocated IP address for said first UE by keeping said allocated IP address information out of the pool of free addresses so that the allocated IP address information is not available to be allocated to any UE other than said first UE since the allocated IP address information is reserved for said first UE.

12. The first network node of claim **11**, wherein the processor is further configured such that, in response to the first network node receiving a PDN connection revoke request message from said second network node, the processor revokes the deleted PDN connection and employs the transmitter to send to the second network node a PDN connection revoke response message.

13. The first network node of claim **11**, wherein the processor reserves said allocated IP address information for said

first UE by placing the allocated IP address information into a reserved address pool comprising a plurality of unreserved IP address information.

14. The first network node of claim **11**, wherein the PDN connection revocable deletion response message comprises said allocated IP address information.

15. The first network node of claim **11**, wherein the PDN connection revocable deletion request comprises one of a Delete Session Request message and a Suspend Notification message.

16. The first network node of claim **11**, wherein the first network node is a Packet Data Gateway (PGW) and the second network node is one of a Mobile Management Entity (MME) and a Serving Gateway (SGW), and the first network node and the second network node are components of an Evolved Packet Core (EPC) network.

17. The first network node of claim **11**, wherein the processor is further configured to release a tunnel previously established with the second network node in response to the PDN connection revocable deletion request message.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,131,485 B2
APPLICATION NO. : 14/509689
DATED : September 8, 2015
INVENTOR(S) : Ronneke et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page, in Item (73), under "Assignee", in Column 1, Line 2, delete "(punl)," and insert -- (publ), --, therefor.

Specification

In Column 6, Line 64, delete "messagest" and insert -- messages --, therefor.

In Column 7, Line 49, delete "claues" and insert -- clauses --, therefor.

Claims

In Column 12, Line 28, in Claim 10, delete "IF addresses" and insert -- IP addresses --, therefor.

In Column 12, Line 36, in Claim 11, delete "comprising;" and insert -- comprising: --, therefor.

Signed and Sealed this
Fourth Day of October, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office